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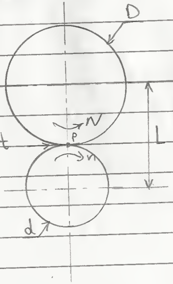
7- Gear measurement

* Friction wheels

- For low power & high friction transmission

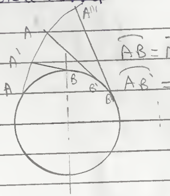


$$\frac{n}{N} = \frac{D}{d}$$

* Gears:

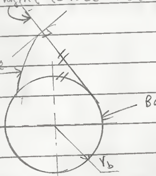
- Positive transmission in which high power is transmitted
- Tooth curves → Involute → Easier to manufacture and weak ⋂
  → Cycloidal → Difficult to manufacture (casting) & strong ⋂
  → Straight for rack
- common normal must intersect centre line for fixed r(N) during contact of tooth interval

* The involute curve:



$\overset{\frown}{AB} = \overline{A'B}$

$\overset{\frown}{AB'} = \overline{A''B'}$



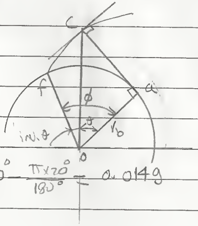
For any point on involute

- Circle a wire around a disk. Pull the wire and remove it as well so wire end draws involute
- Move a pencil around a disk to draw the involute curve
- Tangent on base circle ⊥ involute curve
  Normal to involute curve is tangent to base circle

* Involute function:

- From definition: $\overline{ac} = \widehat{af}$

$$inv.\theta = \phi - \theta = \frac{\widehat{fa}}{r_b} - \theta = \frac{\overline{ac}}{r_b} - \theta$$

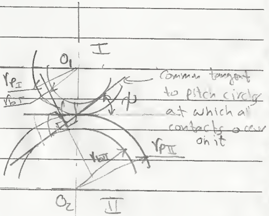


$$inv.\ \theta = \tan\theta - \theta$$

For $\psi = 20°$ (pressure angle): $inv.\theta = \tan 20° - \frac{\pi \times 20°}{180°} = 0.0149$

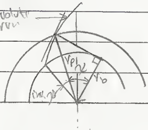
* The pressure angle

- $\psi \downarrow \Rightarrow$ Thrust $F \downarrow$ but it's week



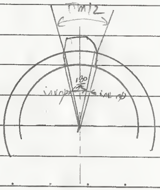
* Relation between pressure angle & circles:

$$\cos\psi = \frac{r_b}{r_p}$$



* Angle of tooth on base circle:

$$\theta = \frac{180}{z} + 2\,inv.\psi$$



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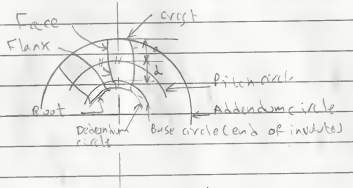
* Parameters of gear



$a = m$

$d = 1.25m$ (for clearance)

Tooth depth $= a + d = 2.25m$

* Experimental prediction of gear module

1- Measure addendum circle (D_a)

2- Count the no. of teeth (Z)

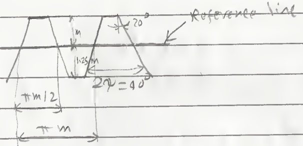
3- Determine the gear module: $D_a = mZ + 2m = m(Z+2)$

4- Select the nearest standard module

* Involute rack:

Tooth thickness (arc) at pitch circle

$$= \frac{\pi D_p}{2Z} = \frac{\pi m Z}{2Z} = \frac{\pi m}{Z}$$



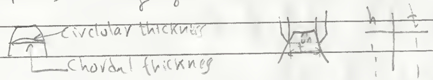
* Experiment: check the form of the tooth flank (involute)

1- Determine the module of gear

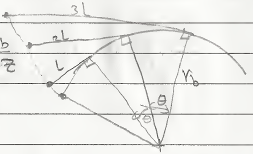
2- Draw the profile of flank of tested gear by

A- Projecting the profile of gear tooth flank using projector

B- Measuring the tooth thickness (chordal) at different tooth depths using gear tooth vernier, T.m.m, etc.



3- Draw the theoretical involute curve for the given module & pressure angle



$$\cos\psi = \frac{D_b}{D_p} = \frac{D_b}{mZ}$$

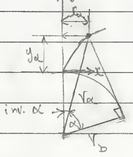
$$D_b = mZ\cos\psi$$

$\theta \to 5^o$

$$L = r_b \times \frac{\theta^o \pi}{180^o}$$

4- Compare the actual profile with the theoretical one

* Drawing of involute curve without drawing of base circle;



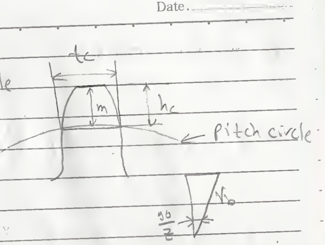
$$x_\alpha = r_\alpha \sin(inv.\alpha)$$
$$y_\alpha = r_\alpha \cos(inv.\alpha) - r_b$$
$$r_\alpha = \frac{r_b}{\cos\alpha} \Rightarrow \alpha = \cos^{-1}\left(\frac{r_b}{r_\alpha}\right)$$

$$inv.\alpha = \tan\alpha - \alpha^{rad.}$$

r_i	α ($\cos^{-1}\frac{r_b}{r_\alpha}$)	$inv\alpha$ ($\tan\alpha - \alpha^{rad}$)	x_α	y_α
r_d				
⋮				
r_p				
⋮				
r_a				

$$r_d = \frac{mZ}{2} - 1.25m = \frac{m}{2}(Z - 2.5)$$
$$r_p = \frac{mZ}{2}$$
$$r_a = \frac{mZ}{2} + m = \frac{m}{2}(Z+2)$$

*Chordal thickness:



(t_c) Chordal thickness of pitch circle

(h_c) Chordal height

$t_c = 2 r_p \sin\left(\frac{90}{z}\right) = 2\left(\frac{mz}{2}\right)\sin\left(\frac{90}{z}\right)$

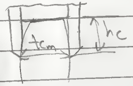
$t_c = mz\sin\left(\frac{90}{z}\right)$

$h_c = m + \left[r_p - r_p\cos\left(\frac{90}{z}\right)\right]$

$h_c = m + \frac{mz}{2}\left[1 - \cos\left(\frac{90}{z}\right)\right]$

○ Experimental procedure:

1- Measure outer diameter
2- Count no. of teeth
3- Determine the module
4- Approximate to the nearest standard module
5- Calculate the chordal height (h_c)
6- Set the vertical vernier of gear tooth vernier on (h_c) value
7- Set it on the tooth tip as shown in figure & measure its thickness (t_{c_m})



8- Calculate the chordal thickness theoretically; $t_c = mz\sin\left(\frac{90}{z}\right)$
9- Determine the error in chordal thickness $\Delta = t_{cm} - t_c$

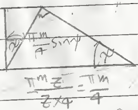
* Constant chord:

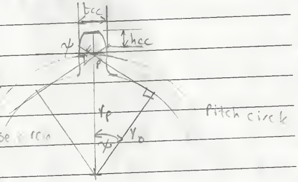
_ (h_{cc}) is constant for all gears of same module

$h_{cc} = m - \frac{\pi m}{4}\cos\varphi\sin\varphi$

$h_{cc} = m\left(1 - \frac{\pi}{4}\cos\varphi\sin\varphi\right)$

$t_{cc} = \frac{\pi m}{2}\cos^2\varphi$

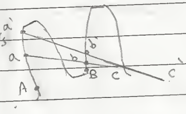




▭ Experimental procedure:

1_ D_o
2_ Z
3_ m
4_ m_{st}
5_ h_{cc}, calculated
6_ t_{cc}, measured by gear tooth vernier
7_ t_{cc}, calculated
8_ $\Delta = t_{cc_m} - t_{cc}$

* Base pitch: Normal distance between 2 invs



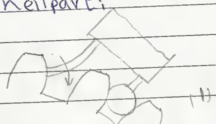
$\overline{AB} = \overline{ab} = \overline{a'b'}$

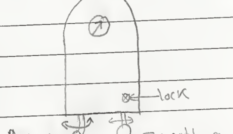
↳ P_b (Base pitch)

$\overline{ac} = \widehat{AC}, \overline{bc} = \overline{BC}$

$P_b = \frac{\pi D_B}{Z} = \frac{\pi m Z\cos\varphi}{Z} = \pi m\cos\varphi$

_ Keilpart:





Move down or up (one direction) and read min. reading (R_g).

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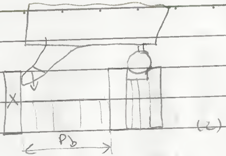
$Pb_m = \cancel{\Delta b} + Pb$

$Pb_m = (R_g - R_{std}) + P_b$

R_g: on gear; R_{std}: Calculated; P_b: intial



Experimental procedure:

1- D_o
2- Z
3- m
4- m_{std}
5- Calculate base pitch: $P_b = \pi m \cos\psi$
6- Select the suitable keilpart according to module (m)
7- Set the keilpart opening to be suitable to measured gear
8- Take the reading on gear tooth as in (1) [least reading]
9- Build a block gauge combination as in (2)
10- Using keilpart to take reading on Combination (R_{std}) [least reading]
11- $\Delta = R_g - R_{std}$
12- $Pb_m = (R_g - R_{std}) + P_b$

- Error → Error in division during manufacturing
  → Error in base circle

* Determination of error in pitch circle:

1- Take reading over all teeth of gear
2- Consider average of readings
3- Compare with standard reading → $R_{av} - R_{std}$
→ $\delta_{av} = R_{av} - R_{std} \rightarrow D_b = \frac{(\delta_{av} + P_b)Z}{\pi}$

$\delta D_b = D_{b_m} - mZ\cos\psi = Z\,\delta_{av}$

K&A ANDLOSYA

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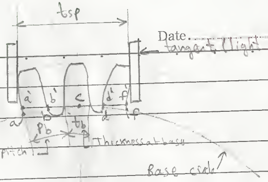
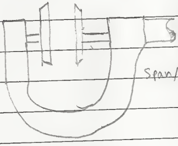


* Span length

- Anvil desingn ensures tangency



Span/gear mike

↳ vernier for large gear

- $\overline{\grave{a}c} = \overset{\frown}{ac}$

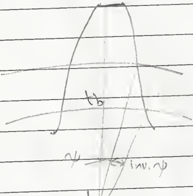
$\grave{a}f' = \overset{\frown}{af}$

$t_{sp} = \overset{\frown}{af}$

- $t_{sp} = (n_{sp} - 1)P_b + t_b$; $n_{sp} = \frac{Z}{9}$ → Approximate to larger

$P_b = t_{sp_{n+1}} - t_{sp_n}$. ↳ $\frac{360}{20 \times 2} = 9$
↳ ψ

$$t_{sp} = (n_{sp} - 1)\pi m \cos\psi + m\left(Z \cos\psi \ \text{inv.}\psi + \frac{\pi}{2}\cos\psi\right)$$



$$t_b = 2\left(r_b \ \text{inv}\psi + \frac{2\pi r_b}{4 \times Z}\right)$$

$$t_b = 2\left(\frac{mZ\cos\psi}{2} \ \text{inv.}\psi + \frac{2\pi mZ\cos\psi}{4 \times Z \times 2}\right)$$

$$t_b = mZ \ \text{inv}\psi \cos\psi + \frac{\pi}{2} m \cos\psi$$